Comments and Author's Replies to the report "Gunnison River / Aspinall Unit Temperature Study - Phase I"

The following are comments and author's replies to the "Gunnison River / Aspinall Unit Temperature Study - Phase I" final report submitted to the Biology Committee of the Upper Colorado River Endangered Fish Recovery Program. Comments pertaining to grammatical / spelling errors have been omitted. These comments pertain specifically to the content of the report and its conclusions.

Comments from Doug Osmundson, U.S. Fish and Wildlife Service.

Osmundson comment: Executive Summary:

At the end of the Introduction section it would be good if a statement could be tacked on explaining what the purpose of the second phase will be. An explanation of phase I is given, but the reader is left wondering what additional info phase II will provide and why a phase II is needed.

Similarly, at the end of Modeling Recommendations, which provides something of an explanation for the need for Phase II, it would be good to tack on the following: "Results from model output in Phase II would help answer the following questions: (list them) ." As it stands, the reader is left wondering why the additional modeling is needed, i.e., what exactly will phase II accomplish and why.

Hydrosphere response: We have added text describing the proposed phase II work, as suggested.

Osmundson comment: Although my suggested candidate months are a good starting point for this analysis, I would say that any additional such analyses not be limited by what I suggested in the referenced report authored by me. These seemed like the most likely months for temperature augmentation given that November-March months likely provide flows that are naturally too cold (< 13 C) for pikeminnow growth. Likewise, I assumed during runoff months of April-May flows would also be too cold for main channel temps at Delta to rise above 13 C. However, I could be all wet on this. There may be opportunity during April and May. Based on the analyses presented in this report, October does not look very promising, yet it is one of the candidate months I suggested targeting for augmentation.

Hydrosphere response: Ok, we can include a wider range of dates when performing analysis on phase II model outputs. The models themselves will likely run over a several year period, and so output and analysis will not be limited to just the five months identified in your report.

<u>Osmundson comment:</u> Page 29. I'm a little confused by the regression. The location described as "above the North Fork" refers to the main fork upstream of the north fork confluence and not the north fork itself?

Also, does the regression of main fork temps upstream of the main two tributaries with main fork temps downstream of the two tributaries really tell us that the tributaries have little influence? You may get a high r-square if you regressed north fork temps against main fork temps at Delta. How would this be interpreted? The author may want to flesh this out a little more to be convincing. However, he has done additional analyses that do add to his argument that tributaries do not have a large impact (see page 31).

Hydrosphere response: The location is the mainstem of the Gunnison above the North fork confluence. There is very little data from the North Fork to test this (I recommend collecting temperature data from the North Fork if possible in the future).

<u>Osmundson comment:</u> Page 31. I like the analysis referred to on page 31 that indicates that a 1C increase in release temps results in a 0.75 C increase at Delta. This to me is the most convincing statement in the report regarding one of the primary conclusions, i.e., that the Aspinall Units have indeed affected main channel temperatures at Delta. However, this assumes that temperatures at the Crystal release site are lower now than they were historically. I'm wondering if some simulations could be done based on this relationship that would indicate just how much the dam has reduced temperatures at Delta on average. If not here, perhaps from the modeling effort in Phase II? Or does such an exercise require historic temperature data from the Crystal site prior to the dam?

Hydrosphere response: Without pre-dam stream temperature data, this would be difficult. One possible option would be to compare temperatures from similar rivers that are unregulated, or to linearly (spatially) interpolate between temperatures above Blue Mesa and well below Crystal where temperatures have clearly returned to ambient conditions (like at Grand Junction, perhaps).

<u>Comments from Dr. Brett Johnson, Dept. of Fishery and Wildlife Biology, Colorado State University.</u>

<u>Johnson comment:</u> Page B- why aren't impacts to reservoir fisheries listed as a possible Constraint? This issue comes up elsewhere in the report, just not in the executive summary.

Hydrosphere response: As the list on page B notes, the list of constraints presented there is not all-inclusive, and reservoir fisheries constraints are mentioned elsewhere.

<u>Johnson comment:</u> Figure 1- can you show the Hartland Diversion? You mention it on page 1 and page 42 and it is relevant with respect to the extent of "trout water" in the Gunnison.

Hydrosphere response: I've added text to describe its location.

Johnson comment: Page 4- is the database you developed for future temperature modeling going to be made available to others in the Basin, for purposes other than those proposed for Phase 2?

Hydrosphere response: Yes, with the Recovery Program’s approval.

Johnson comment: More detailed assessment of data quality and gaps in the available data (and how to remedy them) are necessary.

For example, stream gages are not present on some of the main tributaries to Blue Mesa Reservoir (BMR). Since inflow is such a dominant factor for reservoir thermal modeling, is quantification of tributary inflows needed? Past work has assumed the Gunnison represents 57% of inflow based on statement made by Cudlip et al. in the 1980’s but is this an accurate estimate?

Also, in my experience modeling Blue Mesa, availability of adequate meteorological data may be a serious limiting factor. How do the data from the Delta station represent conditions in the study area? I found that a weather station in Gunnison was not sufficiently close to represent Blue Mesa conditions.

Hydrosphere response: Although there are some data limitations, we do not feel that they are insurmountable for purposes of developing reservoir and river temperature models. As needed, we will use previously published estimates and infrequently recorded data to augment our estimated values.

Johnson comment: Page 7- a better justification for using reservoir temperature profiles to predict outflow temperatures is needed. Why not recommend putting temperature loggers in outflows as we did in 1996?

Hydrosphere response: This would certainly provide accurate data. However, given the currently available data, the use of temperature profiles from the reservoirs is shown to be a valid approach when release temperatures are unavailable.

Johnson comment: Page 8- do releases from BMR really peak in early fall some years?

Hydrosphere response: Actually, peak releases may occur anytime between June and the following winter - I have revised this sentence in the document. In some years, the highest releases are during winter months in anticipation of large spring snowmelt runoff events.

Johnson comment: Page 11, first sentence- this statement could be quantified and backed up with reference to data. I have minimized the longitudinal differences in order to use a 1D thermal model, but in looking at several years of data it looks like the stratification differs among basins throughout the summer. A 3D model seems better for Phase 2.

Hydrosphere response: Although longitudinal differences are not strong for the period of record, there may be a hydrologically-induced gradient that only occurs during very large runoff years. We agree with Brett that a 3D model is preferable, and would be needed to capture such a longitudinal gradient.

Johnson comment: Page 13- How robust is the conclusion that inflow drives stratification and release temperatures? The comparison between 1997 and 2000 ignores possible climatic differences during and after snowmelt in each year that confounds the effect of inflow. In your defense, you do say more data needed to investigate.

Hydrosphere response: Climatic effects may indeed play a role here, however, if you look at the profiles of Figure 10, it is rather more likely that inflow differences caused the variations in the profiles at deeper elevations, where climatic impacts would not be likely to cause those variations. It is quite plausible that the surface differences are climate-induced, at least in part.

Johnson comment: Page 13- why do assume that “the outlet location change would not significantly impact thermal structure of the reservoir”? Is this a reasonable assumption, and if so, why do we need further modeling of a TCD?

Hydrosphere response: Here we are simply making the point that IF reservoir thermal structure did not change, a TCD would result in an approximate 3 degree C increase in release temperature. There is clearly a chance that thermal structure WILL change, and hence we need a model to fully answer the question of how much warmer the release water could be.

Johnson comment: Page 14, Figure 14- can you add elevation as second y-axis so reader can refer to figure to interpret the statements about plunging inflows and release depths at Morrow?

Hydrosphere response: The water surface elevations at Morrow Point are very nearly stationary - varying over the period of data shown by less than 5 meters; therefore, depth is nearly a perfect surrogate for water surface elevation.

Johnson comment: Page 23- third bullet- suggest changing “Increasing the location of the outlet…” to “Raising the outlet…”. Also, the point about impact to fisheries needs to be expanded (its own bullet?). You could say predicting impacts to reservoir fisheries of raising outlet would be beyond the scope of CEQUAL in Phase 2. Such potential impacts include alteration of zooplankton production dynamics, fish distribution and feeding behavior, predator-prey interactions among lake trout and kokanee salmon, and possible changes to fish entrainment (especially kokanee).

Hydrosphere response: We have added language to reflect these possible impacts

Johnson comment: Page 30-5.3- Why not use a multiple regression model to evaluate the all three drivers simultaneously? The data parsing business seemed a little shaky, and results in pretty low sample sizes.

Hydrosphere response: Yes, this is true. In fact, we will be doing a complete multiple-regression analysis as part of phase II. My main goal in phase I was to try to isolate the drivers such that individual impacts of each could be discerned without worrying about interdependencies.

Johnson comment: Page 33- Alternative explanation could be that weather data from Delta do not adequately represent the study reach?

Hydrosphere response: Yes, this may well be part of the issue, although my experience with these systems (and much of the literature out there) leads me to believe that the exclusion of solar radiation is the largest contributor to this discrepancy.

Johnson comment: Page 42, section 6.2.9- actually, some of my work at BMR was prompted by concerns from CDOW that new dam operations could have negative effects on the reservoir productivity and the kokanee fishery. I chose to evaluate thermal effects and discovered that if the reservoir was drawn down enough in summer that epilimnetic water was released it could have consequences for predator-prey interactions among lake trout and kokanee, but only if unrealistically high releases occurred in a dry year. Our most recent modeling using more realistic operations scenarios provided by USBR and USFWS suggest that thermal consequences of a new release pattern (not new release depths) are almost negligible compared to the effects of climate and hydrology (Johnson et al. in prep). I would, however, be more concerned about possible effects of a shallower withdrawal depth since that could conceivably have a thermal effect on the reservoir, and may also present an entrainment issue for zooplankton and kokanee.

Hydrosphere response: I have included the above statement in this section. Thanks for the clarification.

Johnson comment: Page 42, last paragraph- I'd like to see more commentary about the prospects for a TCD to increase DO problems. We have seen alarmingly low DO in Cebolla basin in 2001 and in some previous years. Our best guess as to the cause is some hydrologic/hydrodynamic quirk whereby residence time in Cebolla increases in some years, presumably when Lake Fork inflow exceeds Cebolla Creek inflow. Regardless of the cause, a change to DO patterns due to a TCD would be a concern because it could alter the spatial segregation of lake trout and kokanee. Can CEQUAL handle this aspect well and will DO modeling be a part of Phase 2?

Hydrosphere response: I've added some commentary, but no, DO is not scheduled to be included in the phase II model. However, addition of DO at a later date is certainly feasible.

Johnson comment: Page 44- I was left wishing for more detailed conclusions and recommendations. Can you be more specific about what issues need to be addressed with the "rigorous modeling study" in Phase 2 (e.g., DO issue), and what data gaps will need to be filled before that can proceed? I think you should also leave the reader with an assessment of what concerns will not be addressed by the work proposed in Phase 2 (specifically, the effects on reservoir fisheries).

Hydrosphere response: Again, DO issues are currently outside the scope of work for phase II. I agree that these issues are relevant to the reservoir fishery, but they have not been included in the current scope.

Comments from Jerry Miller, USBR, Upper Colorado River Region.

Miller Comment: can you please explain why dry years often lead to colder release temperatures.

Hydrosphere response: Yes, in wet years, there is significantly more flow through the reservoir, and the reservoir will often have been lowered further during winter months in anticipation of high runoff. Inflows are typically warmer than the reservoir water stored through winter, and thus a larger volume of inflow water tends to result in a seasonally warmer reservoir.

Miller Comment: Would like to see a bit more info on the scope of the work in the introduction, particularly as it impacts phase II.

Hydrosphere response: OK, we've added some details.

Miller Comment: May want to address issue of fish entrainment if a TCD is used

Hydrosphere response: We have addressed this issue in the document, per comments from yourself and Brett Johnson.

Miller Comment: Would like to see minimum and maximum stream temperatures addressed as part of phase II

Hydrosphere response: We have not included this in the current scope for phase II, but time and money permitting we will try to include an analysis of diurnal temperature variations in the project.

Comments from Michelle Garrison and Randy Seaholm, Colorado Water Conservation Board. These comments were provided via paper copy, so they are paraphrased here, with the original attached for reference. The numbers at the end of each comment are from the original CWCB letter, and refer to the section numbers of the report.

CWCB comment: Introduction, page 2, 1st paragraph mentions the effects of irrigation. Irrigation in the Gunnison Basin removes a large volume of water and returns a substantial portion of that water to the stream later, downstream, and much warmer. So the reduction of flows in the river and the return of warmer water should be increasing the temperatures at Delta. How likely is it that the warming effect of irrigation offsets the cooling effects of the Aspinall Unit? Is there any way to estimate the historic water temperature at Delta prior to irrigation (i.e. pre-1850)?

Hydrosphere response: While irrigation will indeed warm the waters that return to the river, the warmest they can be is that of the locally ambient (i.e., unregulated) condition. Mixing locally ambient water with cold water will still result in colder-than-ambient water in the river, so while irrigation returns may dampen the effects of the reservoirs, they certainly will not offset them totally.

There are no pre-reservoir stream temperature data as far as we know.

CWCB comment: Temperature Analysis of the Three Aspinall Unit Reservoirs, page 8, paragraph after figure 3, last sentence: "The temperature differences between each point are more pronounced in the earlier summer months and taper off in late summer." That is not evident by looking at Figure 3. For example, in 1995 the temperatures seem to be higher below Blue Mesa than below Morrow Point. In 1998, there seem to be larger differences in temperature in the late summer than in the earlier summer months, contrary to your statement.

Hydrosphere response: The 1995 data are for two single observations during different months, so I would not use them for a comparison. In 1998, the June 1 difference between Blue Mesa and Crystal is 4 degrees, while on September 1 it is 3 degrees. This is the smallest change seen in the data, but still supports the statement made in the report.

CWCB comment: Data Analysis by Reservoir – Blue Mesa; Blue Mesa Summary, 1st paragraph of section, bottom of page 14. "…the reservoir outlet could be raised by 35 feet and still be able to release water at the lowest historical water surface elevations." Again, it is vital that we know more about the reoperation of the Aspinall Unit before we proceed. It is very likely that water surface elevations will decrease when the Aspinall Unit is operated to meet the NPS water right and USFWS flow recommendations. Would your estimation of a possible increase of temperatures of 3 degrees in wet years and 5 degrees in dry years still hold if the water surface elevations were lowered significantly?

Hydrosphere response: It is possible that in wet years there will be less of a gradient in the reservoirs and hence less flexibility in modifying release temperatures. Climatic conditions in combination with wet and dry years will combine to influence these factors. Nevertheless, some warming will still be achievable.

The argument has been made that we should wait until temperature data can be collected under the altered flow regimes to get a better idea of whether or not a TCD would be useful. While continued data collection will verify the model results, this is the very purpose for which these models are built - to examine before-hand what impacts changed operations will have on reservoir and stream temperatures. The models can be used BEFORE action is taken to examine the impacts.

CWCB comment: River Temperature Analysis; Background on Physical Processes, last sentence of 1st paragraph, page 25. "Heat loss occurs through convection and evaporation at the water surface, and through conductive losses into the streambed when the overlying water is warmer than the bed surface." Would losses in the Black Canyon offset the increased release temperatures?

Hydrosphere response: No. heat losses will not offset warmer releases, because the release temperatures will be *at most* the locally ambient temperature, and most likely still significantly below the ambient temperature, so the net result will be heat gain to the river. It appears that the river reaches an ambient temperature state somewhere between Delta and Grand Junction, although there is not enough data in that area to know where exactly. The ambient temperature itself is a function of local climatic conditions, and so will vary temporally.

CWCB comment: Thermal Characteristics of the Gunnison River from Crystal Dam to Delta, 1st paragraph, middle of page 26. "The Black Canyon is a deeply incised gorge, and shading due to the canyon walls severely restricts radiative heating, even at the summer solstice." Could the Black Canyon be a limiting factor in the ability to raise the temperatures at Delta? Is there some way to increase temperatures in the lower reach where more warming naturally occurs, rather than upstream of the coldest part of the river bed?

Hydrosphere response: While Black Canyon physiography will tend to have a slower warming rate per mile than the more open areas of the river downstream, the river is still going to be warmer at the canyon mouth that at Crystal (see Figure 21).

CWCB comment: 2nd paragraph below Figure 26, last sentence, page 31.

"This indicates that while large tributary inflows may cool the river, they do not contribute so much water to the system as to eliminate the effects of variable release temperatures from Crystal."

While not "eliminating" the effects, do they limit them?. For example, your discussion immediately before Figure 23 stresses the differences in temperature patterns between the mainstem above the North Fork and at Crystal and attributes some of the impacts to tributary flow.

The paragraph before Figure 23 also suggests that in wet years with large reservoir releases, the extra water in the stream (releases and tributary flows) decreases the rate of temperature increase as the water moves downstream. This is expected, but you earlier pointed out that the temperature of reservoir releases is highest in wet years. So in wet years, the effects of releasing warmer water seem to be somewhat negated by the high streamflows that delay the natural warming process.

We are concerned that there may be several of these counterbalancing effects that limit the amount of temperature increase that can be attained at Delta.

Hydrosphere response: This is a valid concern, and one which cannot be addressed without a more rigorous model of the river. We hope to address these issues in phase II.

CWCB comment: We agree that "…the results indicate a great deal of variability in the degree of warming one might expect to achieve…" and think this applies not only to the flow-based temperature control scheme but also to the TCD scheme.

Hydrosphere response: While there is a good deal of variability in both sets of analyses, there are clear indications that of the two, a TCD-based solution is much more likely to achieve the stated temperature targets.

5.4 CWCB comment: Conclusions to River Temperature Analysis, 1st paragraph of section, 2nd sentence, page 36.

"Release temperatures appear to have a significant effect on resulting temperatures at Delta."

Again we believe that no strong conclusions can be drawn and encourage that further study be postponed until reoperation of Aspinall to reflect the NPS water right and USFWS flow recommendations has begun. At that time, new data can be collected that will better represent future stream conditions.

Hydrosphere response: Again, the purpose of these models is to predict what those impacts would be, not to model them after the fact. Reoperation of Aspinall would not affect the way in which a model is developed or calibrated.

CWCB comment: Non-Physical Constraints; Stream Fisheries, 2nd paragraph, 2nd sentence, page 42. "Temperature control with a TCD should not be affected by these flow recommendations."

Preliminary modeling conducted by the CWCB suggests that the USFWS flow recommendations as currently written could in some years significantly affect reservoir storage and releases. This would alter the elevation of the warmer water within Blue Mesa and therefore directly impact the TCD option. More information will be available when the USBR completes its EIS for reoperation of Aspinall based on the USFWS flow recommendations.

Hydrosphere response: please see comments and modifications to this section based on input from Brett Johnson, CSU.

Comments from Tom Chart, Terry Stroh, USBR, Upper Colorado River Region.

Chart/Stroh Comment: #1: what are targets we are trying to meet?

Hydrosphere response: The objective of the report was to address the issue of whether or not the temperature increases identified by Osmundson were achievable through modifications to either flows or release temperatures at the Aspinall Unit reservoirs. Regardless of what temperature targets and constraints need to be considered, a temperature model will help the Recovery Program identify the best way to achieve them.

Chart/Stroh Comment: #2: Where is Delta thermograph?

Hydrosphere response: It is below the confluence with the Uncompahgre (see pp. 28-30, and Figure 26)

Chart/Stroh Comment: #3: Pre-Impoundment Temperature Data?

Hydrosphere response: As far as I know, there are no temperature data for the river before the Aspinall Units were built. The increase in temperatures as defined by Osmundson, and restated in our statement of need, are intended to reproduce a natural or near-natural condition, based on temperature data from other similar rivers (particularly the Yampa).

Chart/Stroh Comment: #4: Confusion / contradiction in flow / temperature relationships

Hydrosphere response: We have tried to clarify this in the report. Generally, the distinction is between impact of release volume as a *"dampener"* of heating rates and the usefulness of modifying release volumes to actually *control* temperatures. While release volume does have some impact on temperatures, it is not of sufficient magnitude to be useful in meeting specific temperature targets.

Chart/Stroh Comment: #5: Impacts of flow recommendations on temperature

Hydrosphere response: Only in the abstract. Changing the release patterns will impact downstream temperatures, although without a model or past history to guide us, it is difficult to quantify. The models proposed for phase II can and will be used to address this question.

Chart/Stroh Comment: #6 and #7: Recovery Goals and Study Purpose:

Hydrosphere response: We couldn't agree more. The models proposed for phase II will provide the Recovery Program a set of tools for scenario analysis that will lead to more informed decisions.

Comments from Melinda Kassen and David Nickum, Colorado Trout Unlimited.

Kassen/Nickum Comment: Why is the trout fishery omitted as a possible non-physical constraint?

Hydrosphere response: This was inadvertent. We had identified the fishery as a constraint, but failed to include it in the final report. A section on the trout fishery has been added to the constraints section.

Kassen/Nickum Comment: The trout fishery extends downstream to the vicinity of the Hartland diversion dam. How might temperature increases impact the lower part of the fishery, where current flow and temperature regimes are already thought to stress the fish?

Hydrosphere response: It is a near certainty that warmer release temperatures would result in warmer water temperatures throughout the downstream reaches. The modeling work proposed for phase II could be used to estimate the net temperature increase at Hartland, or at any number of locations within the fishery reaches.

Kassen/Nickum Comment: Another issue (constraint) with respect to the fishery is the potential impact (beneficial or detrimental) of modified release temperatures on whirling disease. The optimal temperature for the whirling disease parasite is about $14^{o}C$.

Hydrosphere response: We have included this comment as part of the fishery constraint language in the report.